

(q) *Additional required records for natural gas-fueled vehicles.* Composition, including all carbon containing compounds; e.g. CO₂, of the natural gas-fuel used during the test. C₁ and C₂ compounds shall be individually reported. C₃ and heavier hydrocarbons and C₆ and heavier compounds may be reported as a group.

(r) *Additional required records for liquefied petroleum gas-fueled vehicles.* Composition of the liquefied petroleum gas-fuel used during the test. Each hydrocarbon compound present, through C₄ compounds, shall be individually reported. C₅ and heavier hydrocarbons may be reported as a group.

[54 FR 14553, Apr. 11, 1989, as amended at 59 FR 48515, Sept. 21, 1994; 60 FR 34357, June 30, 1995]

§ 86.544–90 Calculations; exhaust emissions.

The final reported test results, with oxides of nitrogen being optional, shall be computed by use of the following formula: (The results of all emission tests shall be rounded, using the “Rounding-Off Method” specified in ASTM E 29–67, to the number of places to the right of the decimal point indicated by expressing the applicable standard to three significant figures.)

$$(a) Y_{wm} = 0.43 \left(\frac{Y_{ct} + Y_s}{D_{ct} + D_s} \right) + 0.57 \left(\frac{Y_{ht} + Y_s}{D_{ht} + D_s} \right)$$

Where:

(1) Y_{wm} = Weighted mass emissions of CO₂ or of each pollutant (*i.e.*, HC, CO, or NO_x) in grams per vehicle kilometer and if appropriate, the weighted carbon mass equivalent of total hydrocarbon equivalent, in grams per vehicle kilometer.

(2) Y_{ct} = Mass emissions as calculated from the “transient” phase of the cold-start test, in grams per test phase.

(3) Y_{ht} = Mass emissions as calculated from the “transient” phase of the hot-start test, in grams per test phase.

(4) Y_s = Mass emissions as calculated from the “stabilized” phase of the cold-start test, in grams per test phase.

(5) D_{ct} = The measured driving distance from the “transient” phase of the cold-start test, in kilometers.

(6) D_{ht} = The measured driving distance from the “transient” phase of the hot-start test, in kilometers.

(7) D_s = The measured driving distance from the “stabilized” phase of the cold-start test, in kilometers.

(b) The mass of each pollutant for each phase of both the cold-start test and the hot-start test is determined from the following:

(1) Hydrocarbon mass:

$$HC_{mass} = V_{mix} \times \text{Density}_{HC} \times (HC_{conc}/1,000,000)$$

(2) Oxides of nitrogen mass:

$$NOx_{mass} = V_{mix} \times \text{Density}_{NO_2} \times K_H \times (NOx_{conc}/1,000,000)$$

(3) Carbon monoxide mass:

$$CO_{mass} = V_{mix} \times \text{Density}_{CO} \times (CO_{conc}/1,000,000)$$

(4) Carbon dioxide mass:

$$CO_{2mass} = V_{mix} \times \text{Density}_{CO_2} \times (CO_{2conc}/100)$$

(5) Methanol mass:

$$CH_3OH_{mass} = V_{mix} \times \text{Density}_{CH_3OH} \times (CH_3OH_{conc}/1,000,000)$$

(6) Formaldehyde mass:

$$HCHO_{mass} = V_{mix} \times \text{Density}_{HCHO} \times (HCHO_{conc}/1,000,000)$$

(7) Total hydrocarbon equivalent:

$$(i) THCE = HC_{mass} + 13.8756/32.042 \times (CH_3OH)_{mass} + 13.8756/30.0262 \times (HCHO)_{mass}$$

(c) Meaning of symbols:

(1) (i) HC_{mass} = Hydrocarbon emissions, in grams per test phase.

(ii) $Density_{HC}$ = Density of HC in exhaust gas.

(A) *For gasoline-fuel*; $Density_{HC}$ = 576.8 g/m³-carbon atom (16.33 g/ft³-carbon atom), assuming an average carbon to hydrogen ratio of 1:1.85, at 20 °C (68 °F) and 101.3 kPa (760 mm Hg) pressure.

(B) *For natural gas and liquefied petroleum gas-fuel*; $Density_{HC}$ = 41.57(12.011+H/C(1.008)) g/m³-carbon atom (1.1771(12.011+H/C(1.008)) g/ft³-carbon atom) where H/C is the hydrogen to carbon ratio of the hydrocarbon components of test fuel, at 20 °C (68 °F) and 101.3 kPa (760mm Hg) pressure.

(iii) (A) HC_{conc} = Hydrocarbon concentration of the dilute exhaust sample corrected for background, in ppm carbon equivalent, *i.e.*, equivalent propane x 3.

(B) $HC_{conc} = HC_e - HC_d(1 - (1/DF))$

Where:

(iv) (A) HC_e = Hydrocarbon concentrations of the dilute exhaust sample as

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measured, in ppm carbon equivalent (propane ppm x 3).

(B) $HC_e = FIDHC_e - (r)C_{CH_3OHe}$

(v) FID HC_e = Concentration of hydrocarbon (plus methanol if methanol-fueled motorcycle is tested) in dilute exhaust as measured by the FID ppm carbon equivalent.

(vi) r = FID response to methanol.

(vii) C_{CH_3OHe} = Concentration of methanol in dilute exhaust as determined from the dilute exhaust methanol sample, ppm carbon.

(viii)(A) HC_d = Hydrocarbon concentration of the dilution air as measured, ppm carbon equivalent.

(B) $HC_d = FID HC_d - (r)C_{CH_3OHd}$

(ix) FID HC_d = Concentration of hydrocarbon (plus methanol if methanol-fueled motorcycle is tested) in dilution air as measured by the FID, ppm carbon equivalent.

(x) C_{CH_3OHd} = Concentration of methanol in dilution air as determined from dilution air methanol sample, ppm carbon.

(2)(i) $NO_{x, mass}$ = Oxides of nitrogen emissions, grams per test phase.

(ii) $Density_{NO_2}$ = Density of oxides of nitrogen in the exhaust gas, assuming they are in the form of nitrogen dioxide, 1913 g/m³ (54.16 g/ft³), at 20 °C (68 °F) and 101.3 kPa (760 mm Hg) pressure.

(iii)(A) $NO_{x, conc}$ = Oxides of nitrogen concentration of the dilute exhaust sample corrected for background, ppm.

(B) $NO_{x, conc} = NO_{xe} - NO_{xd}(1 - (1/DF))$

Where:

(iv) NO_{xe} = Oxides of nitrogen concentration of the dilute exhaust sample as measured, ppm.

(v) NO_{xd} = Oxides of nitrogen concentration of the dilution air as measured, ppm.

(3)(i) CO_{mass} = Carbon monoxide emissions, in grams per test phase.

(ii) $Density_{CO}$ = Density of carbon monoxide, 1164 g/m³ (32.97 g/ft³), at 20 °C (68 °F) and 101.3 kPa (760 mm Hg) pressure.

(iii)(A) CO_{conc} = Carbon monoxide concentration of the dilute exhaust sample corrected for background, water vapor, and CO₂ extraction, ppm.

(B) $CO_{conc} = CO_e - CO_d(1 - (1/DF))$

Where:

(iv)(A) CO_e = Carbon monoxide concentration of the dilute exhaust sample

volume corrected for water vapor and carbon dioxide extraction, in ppm.

(B) $CO_e = (1 - 0.01925CO_{2e} - 0.000323R)CO_{em}$ for gasoline-fueled vehicles with hydrogen to carbon ratio of 1.85:1

(C) $CO_e = [1 - (0.01 + 0.005HCR) CO_{2e} - 0.000323R]CO_{em}$ for methanol-fueled, natural gas-fueled or liquefied petroleum gas-fueled motorcycles, where HCR is hydrogen to carbon ratio as measured for the fuel used.

(v) CO_{em} = Carbon monoxide concentration of the dilute exhaust sample as measured, ppm

(vi) CO_{2e} = Carbon dioxide concentration of the dilute exhaust sample, pct.

(vii) R = Relative humidity of the dilution air, pct (see § 86.542(n)).

(viii)(A) CO_d = Carbon monoxide concentration of the dilution air corrected for water vapor extraction, ppm.

(B) $CO_d = (1 - 0.000323R)CO_{dm}$

Where:

(ix) CO_{dm} = Carbon monoxide concentration of the dilution air sample as measured, ppm.

NOTE: If a CO instrument which meets the criteria specified in § 86.511 is used and the conditioning column has been deleted, CO_{em} can be substituted directly for CO_e and CO_{dm} must be substituted directly for CO_d .

(4)(i) $CO_{2, mass}$ = Carbon dioxide emissions, grams per test phase.

(ii) $Density_{CO_2}$ = Density of carbon dioxide, 1830 g/m³ (51.81 g/ft³), at 20 °C (68 °F) and 101.3 kPa (760 mm Hg) pressure.

(iii)(A) $CO_{2, conc}$ = carbon dioxide concentration of the dilute exhaust sample corrected for background, in percent.

(B) $CO_{2, conc} = CO_{2e} - CO_{2d}(1 - 1/DF)$

Where:

(iv) CO_{2d} = Carbon dioxide concentration of the dilution air as measured, in percent.

(5)(i) CH_3OH_{mass} = Methanol emissions corrected for background, grams per test phase.

(ii) $Density_{CH_3OH}$ = Density of methanol is 1332 g/m³ (37.71 g/ft³), at 20 °C (68 °F) and 101.3 kPa (760 mm Hg) pressure.

(iii)(A) CH_3OH_{conc} = Methanol concentration of the dilute exhaust corrected for background, ppm.

(B) $CH_3OH_{conc} = C_{CH_3OHe} - C_{CH_3OHd}(1 - (1/DF))$

Where:

(iv)(A) C_{CH_3OHe} = Methanol concentration in the dilute exhaust, ppm.

(B)

$$C_{\text{CH}_3\text{OH}_e} = \frac{3.813 \times 10^{-2} \times T_{\text{EM}} \left[(C_{\text{S1}} \times AV_{\text{S1}}) + (C_{\text{S2}} \times AV_{\text{S2}}) \right]}{P_B \times V_{\text{EM}}}$$

(v)(A) $C_{\text{CH}_3\text{OH}_d}$ = Methanol concentration in the dilution air, ppm. (B)

$$C_{\text{CH}_3\text{OH}_d} = \frac{3.813 \times 10^{-2} \times T_{\text{DM}} \left[(C_{\text{D1}} \times AV_{\text{D1}}) + (C_{\text{D2}} \times AV_{\text{D2}}) \right]}{P_B \times V_{\text{DM}}}$$

(vi) T_{EM} = Temperature of methanol sample withdrawn from dilute exhaust, °R.

(vii) T_{DM} = Temperature of methanol sample withdrawn from dilution air, °R.

(viii) P_B = Barometric pressure during test, mm Hg.

(ix) V_{EM} = Volume of methanol sample withdrawn from dilute exhaust, ft³.

(x) V_{DM} = Volume of methanol sample withdrawn from dilution air, ft³.

(xi) C_s = GC concentration of sample drawn from dilute exhaust, µg/ml.

(xii) C_D = GC concentration of sample drawn from dilution air, µg/ml.

(xiii) AV_s = Volume of absorbing reagent (deionized water) in impinger through which methanol sample from dilute exhaust is drawn, ml.

(xiv) AV_D = Volume of absorbing reagent (deionized water) in impinger

through which methanol sample from dilution air is drawn, ml.

(xv) 1 = first impinger.

(xvi) 2 = second impinger.

(6)(i) $\text{HCHO}_{\text{mass}}$ = Formaldehyde emissions corrected for background, grams per test phase.

(ii) $\text{Density}_{\text{HCHO}}$ = Density of formaldehyde is 1249 g/m³ (35.36 g/ft³), at 20 °C (68 °F) and 101.3 kPa (760 mm Hg) pressure.

(iii)(A) $\text{HCHO}_{\text{conc}}$ = Formaldehyde concentration of the dilute exhaust corrected for background, ppm.

(B) $\text{HCHO}_{\text{conc}} = C_{\text{HCHO}_e} - C_{\text{HCHO}_d} (1 - (1/DF))$

Where:

(iv)(A) C_{HCHO_e} = Formaldehyde concentration in dilute exhaust, ppm.

(B)

$$C_{\text{HCHO}_e} = \frac{4.069 \times 10^{-2} \times C_{\text{FDE}} \times V_{\text{AE}} \times Q \times T_{\text{EF}}}{V_{\text{SE}} \times P_B}$$

(v)(A) C_{HCHO_d} = Formaldehyde concentration in dilution air, ppm. (B)

$$C_{\text{HCHO}_d} = \frac{4.069 \times 10^{-2} \times C_{\text{FDA}} \times V_{\text{AA}} \times Q \times T_{\text{DF}}}{V_{\text{SA}} \times P_B}$$

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(vi) C_{FDE} = Concentration of DNPH derivative of formaldehyde from dilute exhaust sample in sampling solution, $\mu\text{g/ml}$.

(vii) V_{AE} = Volume of sampling solution for dilute exhaust formaldehyde sample, ml.

(viii)(A) Q = Ratio of molecular weights of formaldehyde to its DNPH derivative.

(B) $Q = 0.1429$

(ix) T_{EF} = Temperature of formaldehyde sample withdrawn from dilute exhaust, $^{\circ}\text{R}$.

(x) V_{SE} = Volume of formaldehyde sample withdrawn from dilute exhaust, ft^3 .

(xi) P_B = Barometric pressure during test, mm Hg.

(xii) C_{FDA} = Concentration of DNPH derivative of formaldehyde from dilu-

tion air sample in sampling solution, $\mu\text{g/ml}$.

(xiii) V_{AA} = Volume of sampling solution for dilution air formaldehyde sample, ml.

(xiv) T_{DF} = Temperature of formaldehyde sample withdrawn from dilution air, $^{\circ}\text{R}$.

(xv) V_{SA} = Volume of formaldehyde sample withdrawn from dilution air, ft^3 .

(7)(i) $DF = 13.4/[\text{CO}_{2e} + (\text{HC}_e = \text{CO}_e)10^{-4}]$ for gasoline-fueled vehicles.

(ii) For methanol-fueled, natural gas-fueled or liquefied petroleum gas-fueled motorcycles, where fuel composition is $\text{C}_x\text{H}_y\text{O}_z$ as measured, or calculated, for the fuel used (for natural gas and liquefied petroleum gas-fuel, $Z=0$):

$$DF = \frac{(100) \frac{x}{(x+y/2+3.76)(x+y/2-z/2)}}{\text{CO}_{2e} + (\text{HC}_e + \text{CO}_e + \text{CH}_3\text{OH}_e = \text{HCHO}_e) \times 10^{-4}}$$

(iii)(A) V_{mix} = Total dilute exhaust volume in cubic meters per test phase corrected to standard conditions (293 $^{\circ}\text{K}$ (528 $^{\circ}\text{R}$) and 101.3 kPa (760 mm Hg)).

(B)

$$V_{\text{mix}} = \frac{V_o \times N \times (P_B - P_i) \times 293}{101.3 \times T_p}$$

Where:

(iv) V_o = Volume of gas pumped by the positive displacement pump, in cubic meters per revolution. This volume is dependent on the pressure differential across the positive displacement pump. (See calibration techniques in § 86.519.)

(v) N = Number of revolutions of the positive displacement pump during the test phase while samples are being collected.

(vi) P_B = Barometric pressure, kPa.

(vii) P_i = Pressure depression below atmospheric measured at the inlet to the positive displacement pump, kPa.

(viii) T_p = Average temperature of dilute exhaust entering positive displace-

ment pump during test while samples are being collected, $^{\circ}\text{K}$.

(ix)(A) K_h = Humidity correction factor.

(B) $K_h = 1/[1 - 0.0329(H - 10.71)]$

Where:

(x)(A) H = Absolute humidity in grams of water per kilogram of dry air.

(B) $H = [(6.211)R_a \times P_d]/[P_B - (P_d \times R_a/100)]$

(xi) R_a = Relative humidity of the ambient air, pct.

(xii) P_d = Saturated vapor pressure, in kPa at the ambient dry bulb temperature.

(xiii) P_B = Barometric pressure, kPa.

(d) Sample calculation of mass emission values for gasoline-fueled vehicles with engine displacements equal to or greater than 170 cc (10.4 cu. in.):

(1) For the "transient" phase of the cold-start test, assume $V_o = 0.0077934 \text{ m}^3$ per rev; $N = 12,115$; $R = 20.5$ pct; $R_a = 20.5$ pct; $P_B = 99.05$ kPa; $P_d = 3.382$ kPa; $P_i = 9.851$ kPa; $T_p = 309.8$ $^{\circ}\text{K}$; $\text{HC}_e = 249.75$ ppm carbon equivalent; $\text{NOx}_e = 38.30$ ppm; $\text{CO}_{em} = 311.23$ ppm; $\text{CO}_{2e} = 0.415$ percent; $\text{HC}_d = 4.90$ ppm; $\text{NOx}_d =$

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0.30 ppm; CO_{dm} = 8.13 ppm; CO_{2d} = 0.037 pct; D_{ct} = 5.650 km.

Then:

(i) $V_{\text{mix}} = [(0.0077934)(12,115)(99.05 - 9.851)(293.15)] / [(101.325)(309.8)] = 78.651 \text{ m}^3 \text{ per test phase.}$

(ii) $H = [(6.211)(20.5)(3.382)] / [(99.05) - (3.382)(20.5/100)] = 4.378 \text{ grams H}_2\text{O per kg dry air.}$

(iii) $K_h = 1/[1 - 0.0329(4.378 - 10.71)] = 0.8276$

(iv) $\text{CO}_e = [1 - 0.01925(0.415) - 0.000323(20.5)](311.23) = 306.68 \text{ ppm.}$

(v) $\text{CO}_d = [1 - 0.000323(20.5)](8.13) = 8.08 \text{ ppm.}$

(vi) $\text{DF} = 13.4/[0.415 + (249.75 + 306.68)10^{-4}] = 28.472$

(vii) $\text{HC}_{\text{conc}} = 249.75 - 4.90(1 - 1/28.472) = 245.02 \text{ ppm.}$

(viii) $\text{HC}_{\text{mass}} = (78.651)(576.8)(245.02)10^{-6} = 11.114 \text{ grams per test phase.}$

(ix) $\text{NOx}_{\text{conc}} = 38.30 - 0.30(1 - 1/28.472) = 38.01 \text{ ppm.}$

(x) $\text{NOx}_{\text{mass}} = (78.651)(1913)(38.01)(0.8276) \times 10^{-6} = 4.733 \text{ grams per test phase.}$

(xi) $\text{CO}_{\text{conc}} = 306.68 - 8.08(1 - 1/28.472) = 298.88 \text{ ppm.}$

(xii) $\text{CO}_{\text{mass}} = (78.651)(1164)(298.88)10^{-6} = 27.362 \text{ grams per test phase.}$

(xiii) $\text{CO}_{2\text{conc}} = 0.415 - 0.037(1 - 1/28.472) = 0.3793 \text{ percent.}$

(xiv) $\text{CO}_{2\text{mass}} = (78.651)(1843)(0.3793)/100 = 549.81 \text{ grams per test phase.}$

(2) For the “stabilized” portion of the cold-start test, assume that similar calculations resulted in HC_{mass} = 7.184 grams per test phase; NOx_{mass} = 2.154 grams per test phase; CO_{mass} = 64.541 grams per test phase; and CO_{2mass} = 529.52 grams per test phase. D_s = 6.070 km.

(3) For the “transient” portion of the hot-start test, assume that similar calculations resulted in HC_{mass} = 6.122 grams per test phase; NOx_{mass} = 7.056 grams per test phase; CO_{mass} = 34.964 grams per test phase; and CO_{2mass} = 480.93 grams per test phase. D_{ht} = 5.660 km.

(4) For a 1978 motorcycle with an engine displacement equal to or greater than 170 cc (10.4 cu. in.):

(i) $\text{HC}_{\text{wm}} = 0.43 [(11.114 + 7.184)/(5.650 + 6.070)] + 0.57 [(6.122 + 7.184)/(5.660 + 6.070)] = 1.318 \text{ grams per vehicle kilometer.}$

(ii) $\text{NOx}_{\text{wm}} = 0.43 [(4.733 + 2.154)/(5.650 + 6.070)] + 0.57 [(7.056 + 2.154)/(5.660 +$

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6.070)] = 0.700 gram per vehicle kilometer.

(iii) $\text{CO}_{\text{wm}} = 0.43 [(27.362 + 64.541)/(5.650 + 6.070)] + 0.57 [(34.964 + 64.541)/(5.660 + 6.070)] = 8.207 \text{ grams per vehicle kilometer.}$

(iv) $\text{CO}_{2\text{wm}} = 0.43 [(549.81 + 529.52)/(5.650 + 6.070)] + 0.57 [(480.93 + 529.52)/(5.660 + 6.070)] = 88.701 \text{ grams per vehicle kilometer.}$

[54 FR 14553, Apr. 11, 1989, as amended at 59 FR 48515, Sept. 21, 1994; 60 FR 34358, June 30, 1995]

Subpart G—Selective Enforcement Auditing of New Light-Duty Vehicles

SOURCE: 41 FR 31483, July 28, 1976, unless otherwise noted.

§ 86.601-84 Applicability.

For 1984 and later model year light-duty vehicles, all provisions of this subpart are applicable. The provisions of this subpart are not applicable to 1984 and later model year light-duty trucks.

(a) *Section numbering; construction.* (1) The model year of initial applicability is indicated by the two digits following the hyphen of the section number. A section remains in effect for subsequent model years until it is superseded.

(2) A section reference without a model year suffix shall be interpreted to be a reference to the section applicable to the appropriate model year.

(b) References in this subpart to engine families and emission control systems shall be deemed to refer to durability groups and test groups as applicable for manufacturers certifying new light-duty vehicles and light-duty trucks under the provisions of subpart S of this part.

(Secs. 206, 208(a) and 301(a), Clean Air Act, as amended, 42 U.S.C. 7525, 7542(a) and 7601(a))

[49 FR 69, Jan. 3, 1984. Redesignated at 54 FR 2122, Jan. 19, 1989, as amended at 62 FR 31234, June 6, 1997; 64 FR 23922, May 4, 1999]

§ 86.602-84 Definitions.

(a) The definitions in this section apply to this subpart.